Upsilon Studies in Pb-Pb and p-Pb Collisions Using ALICE Muon Spectrometer

ALICE-INDIA MEETING
IIT, Bombay, 27 April 2013

Palash Khan
Saha Institute Of Nuclear Physics,KOLKATA

On behalf of the Upsilon2mumu PAG

Plan of My Talk

- Physics Motivation
- Detector and Data Taking
- Analysis on Nuclear Modification Factor
- Results on Pb-Pb:

  R_{AA} vs Npart
  R_{AA} vs Rapidity
  and Comparison With The Theoretical Model

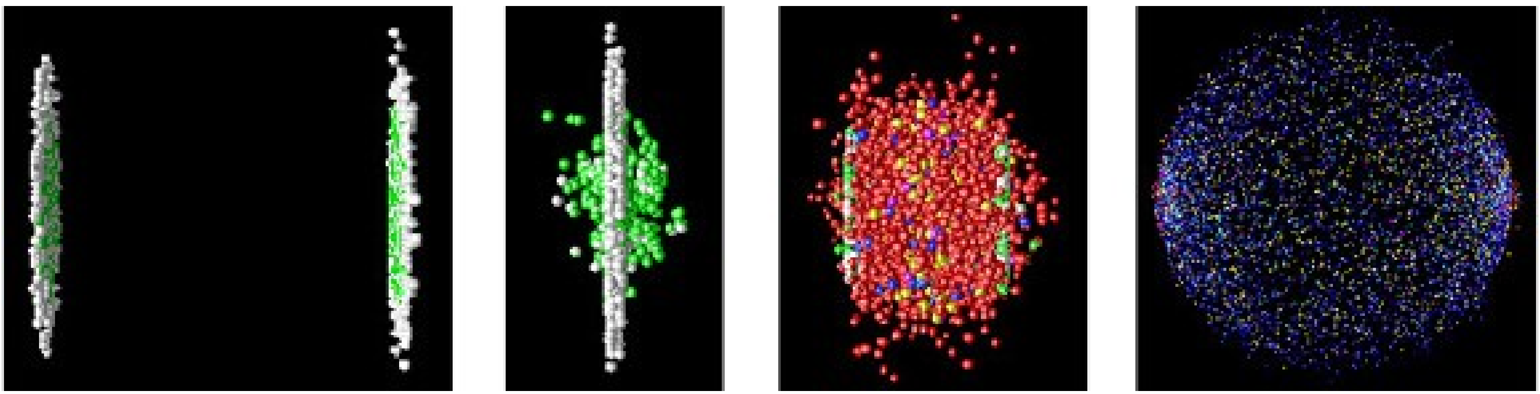
- Results on p-Pb and Pb-p:

  R_{pA} and R_{Ap}
  Forward Backward Ratio R_{FB}

- Summary and Outlook

Physics Motivation

The motivation is to study the particle physics under extreme high density (~ 25 GeV/fm^3) and temperature (~ 5x10^{12} K), when the quarks and gluons are no longer confined within the dimension of the nucleon, but free to move over the volume of high temperature and/or density, called quark-gluon-plasma (QGP).



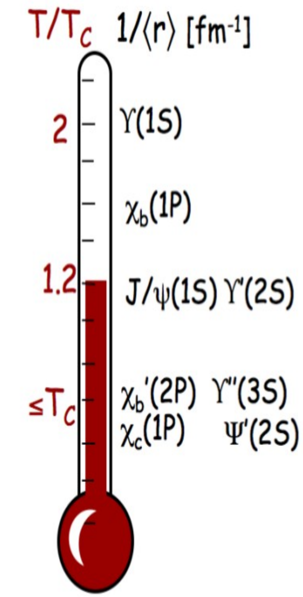


Fig. 5. The QGP thermometer.
Agnes Mocsy, Eur.Phys.J.C61, 2009

- Quarkonia (J/psi and Upsilon) suppression is considered as one of the most striking signatures for QGP formation in AA collisions.
- Charm (1.29 GeV) and Bottom (4.19 GeV) quarks are massive
- Formation takes place at very early stage of the collision
- Sequential suppression pattern of quarkonia production reveal the information about the temperature of the produced medium and acts as a QGP thermometer.
- Measurements of the Y resonances are particularly important since the theoretical calculations are more robust than for the charmonium family due to the heavy bottom quark and the absence of b-hadron feed-down and less recombination than charm.

Detector and Data Taking

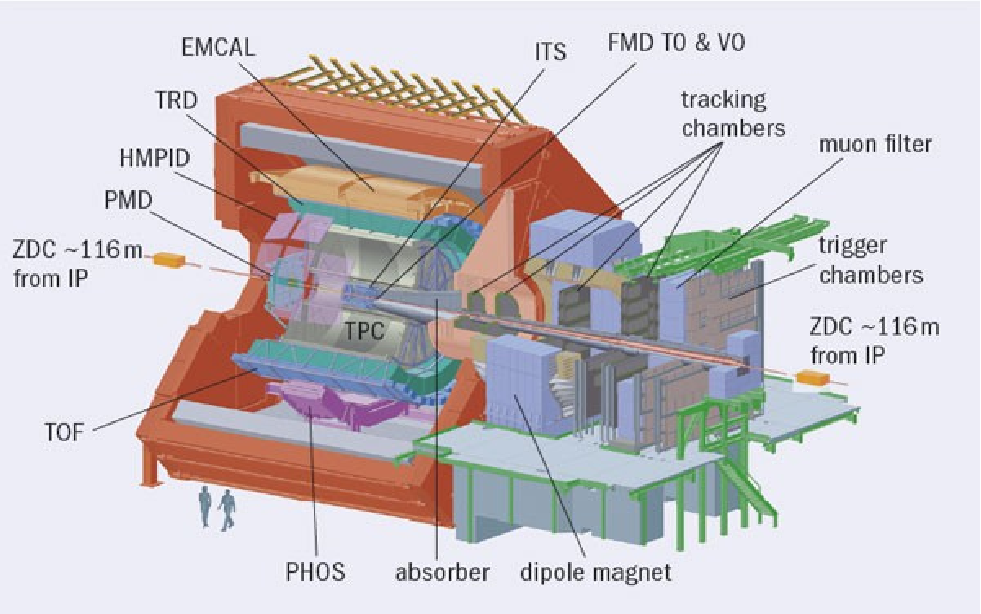
- Forward Rapidity: $2.5 < \eta < 4.0$
- Acceptance down to pT ~ 0 GeV
- Upsilon(Y) → $\mu^+\mu^-$
- Three Resonances (lifetime ~ 10^{-20} s):

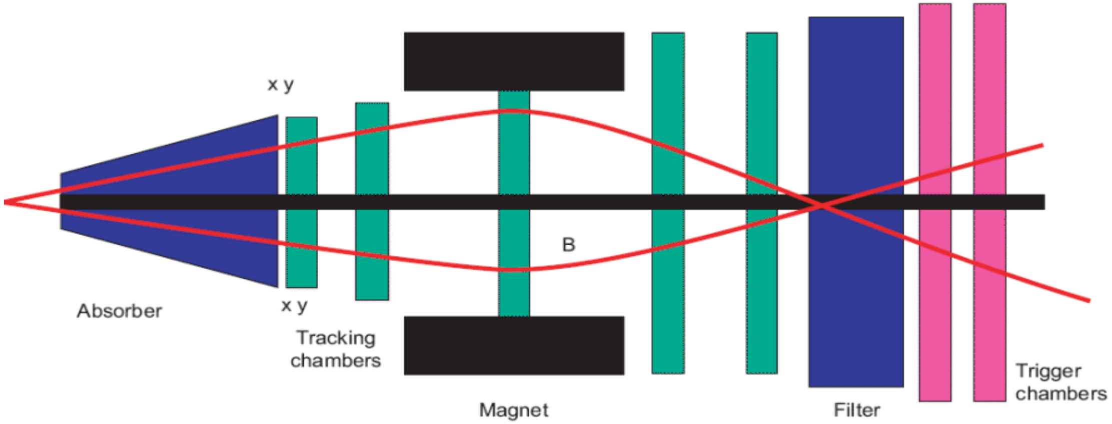
  Y(1S) → 9.460 GeV

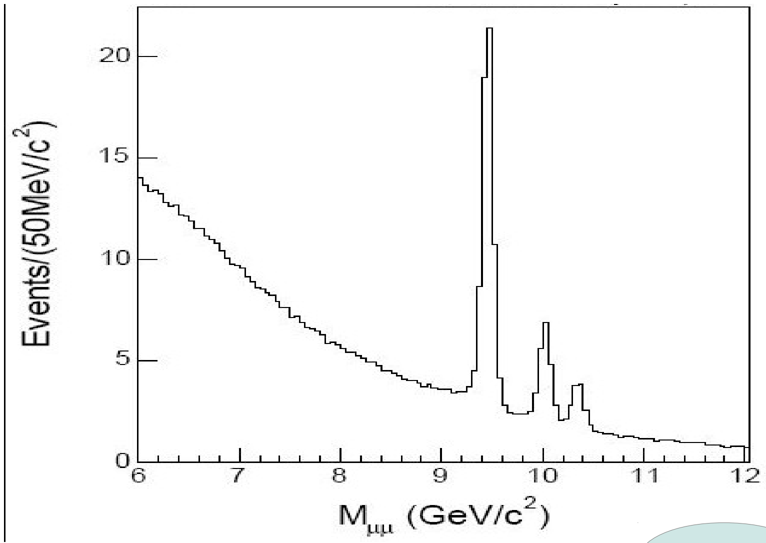
  Y(2S) → 10.023 GeV

  Y(3S) → 10.355 GeV

  - In 2011 around 70 μb^{-1} PbPb data collected at energy 2.76 TeV







$$p^{\mu} p_{\mu} = M^2$$

Nuclear Modification Factor (R_{AA})

The suppression of quarkonia can be quantified by calculating the Nuclear Modification Factor (R_{AA}), which is the ratio of the production in A-A collisions to the production in p+p scaled by the number of binary collisions.

$$R_{AA} = \frac{N_{\Upsilon(1S)}}{\langle AccxEff \rangle_{\Upsilon(1S)} \; x \; \langle T_{AA} \rangle \; x \; N_{MB} \; x \; BR_{\Upsilon(1S)} \; x \; \sigma^{pp}_{\Upsilon(1S)}}$$

$N_{Y(1S)}$ → number of raw Y(1S) yield over background

AccXEff → correction factor for acceptance and efficiency of our detector

T_{AA} → nuclear overlap function

N_{MB} → number of minimum bias events analyzed

$BR_{Y(1S)}$ → branching ratio of upsilon decaying to dimuons (2.48 ± 0.05) %

$\sigma^{pp}{}_{Y(1S)}$A → differential cross-section in pp collision at center of mass energy 2.76 TeV

Pb-Pb ANALYSIS

Signal Extraction

Event Cuts:
Physics Selection
CMUL Trigger
Centrality (0-90) %

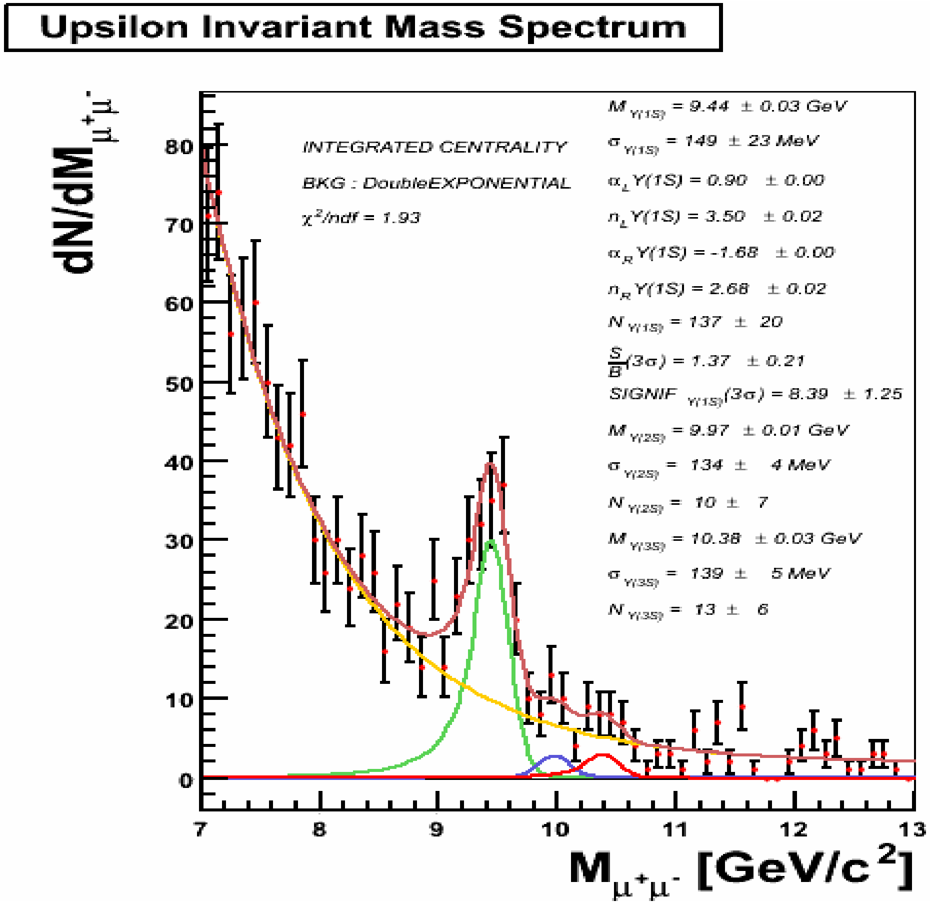
Muon Cuts:
Trigger Matched Track (Lpt,Lpt)
-4.0 < η < -2.5
17.6 cm < R abs < 89.5 cm
pDCA Selection
pT >= 2 GeV

Dimuon Cuts:
-4.0 < y < -2.5

$$M_{Y(2S)} = M^{PDG}_{Y(2S)} + (M^{FIT}_{Y(1S)} - M^{PDG}_{Y(1S)}) \frac{M^{PDG}_{Y(2S)}}{M^{PDG}_{Y(1S)}}$$

$$M_{Y(3S)} = M^{PDG}_{Y(3S)} + (M^{FIT}_{Y(1S)} - M^{PDG}_{Y(1S)}) \frac{M^{PDG}_{Y(3S)}}{M^{PDG}_{Y(1S)}}$$

$$\sigma_{Y(2S)} = \sigma_{Y(1S)} \frac{M^{PDG}_{Y(2S)}}{M^{PDG}_{Y(1S)}} \qquad \sigma_{Y(3S)} = \sigma_{Y(1S)} \frac{M^{PDG}_{Y(3S)}}{M^{PDG}_{Y(1S)}}$$



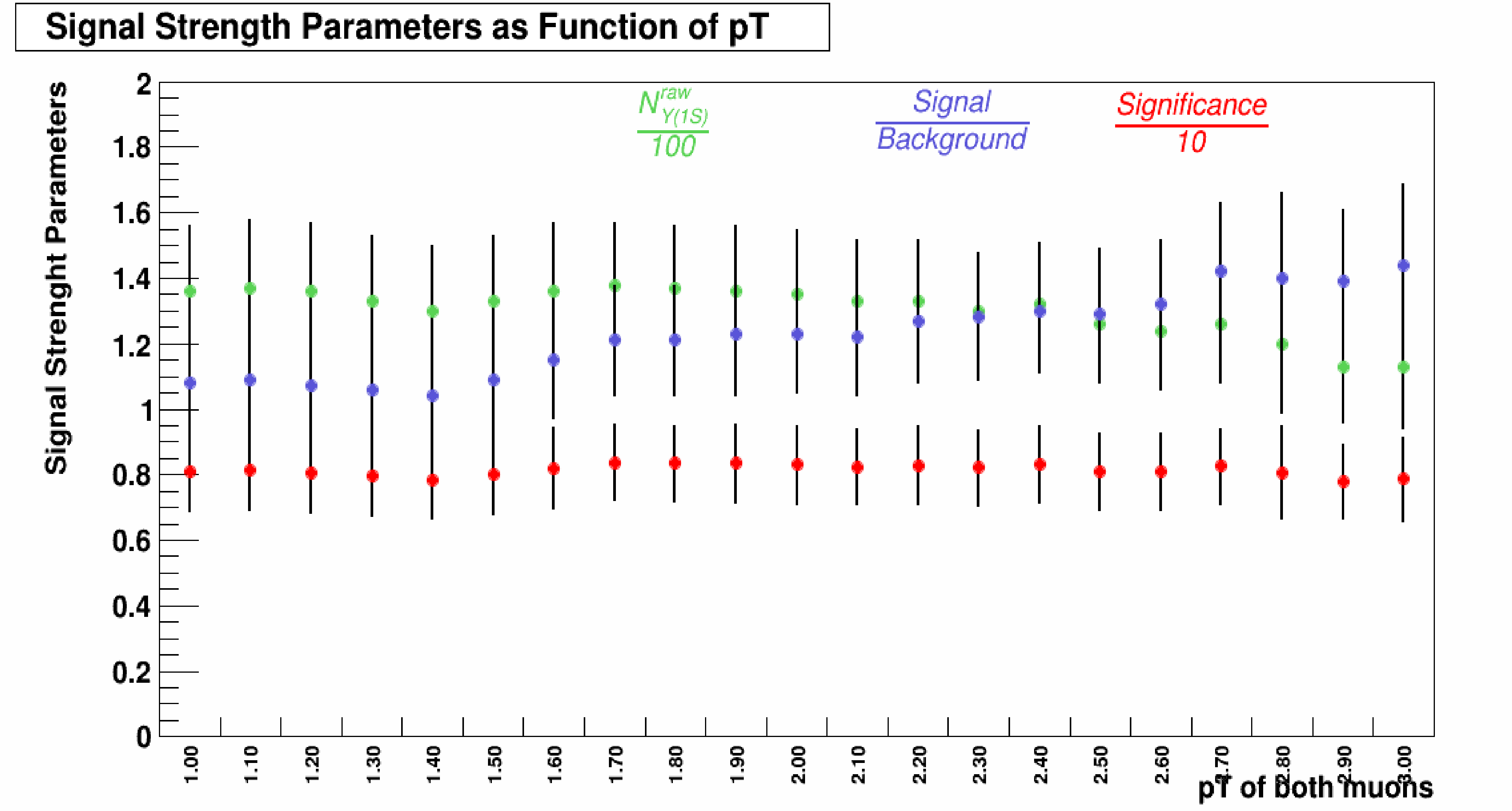
→ Signal fitted with Double Crystal Ball

→ Tail parameters taken from embedding (Javier)

→ Mass, Sigma and Amplitude free for Y(1S)

→ Amplitude of Y(2S) and Y(3S) kept free

Signal Strength Parameters

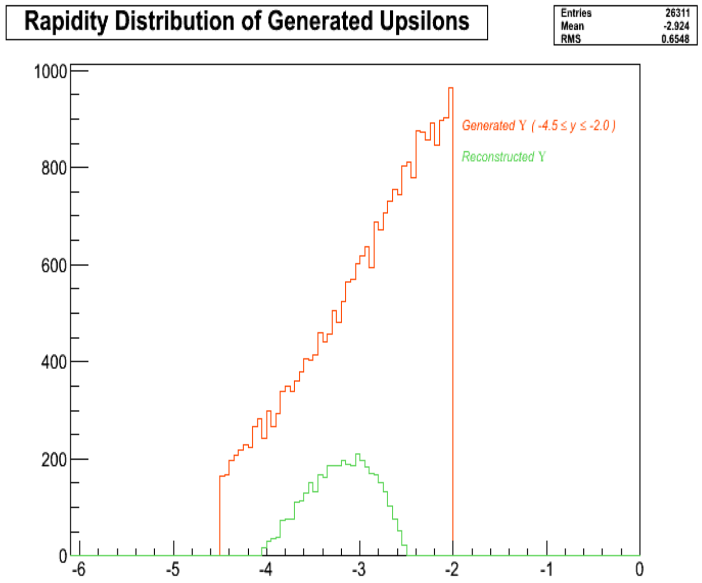


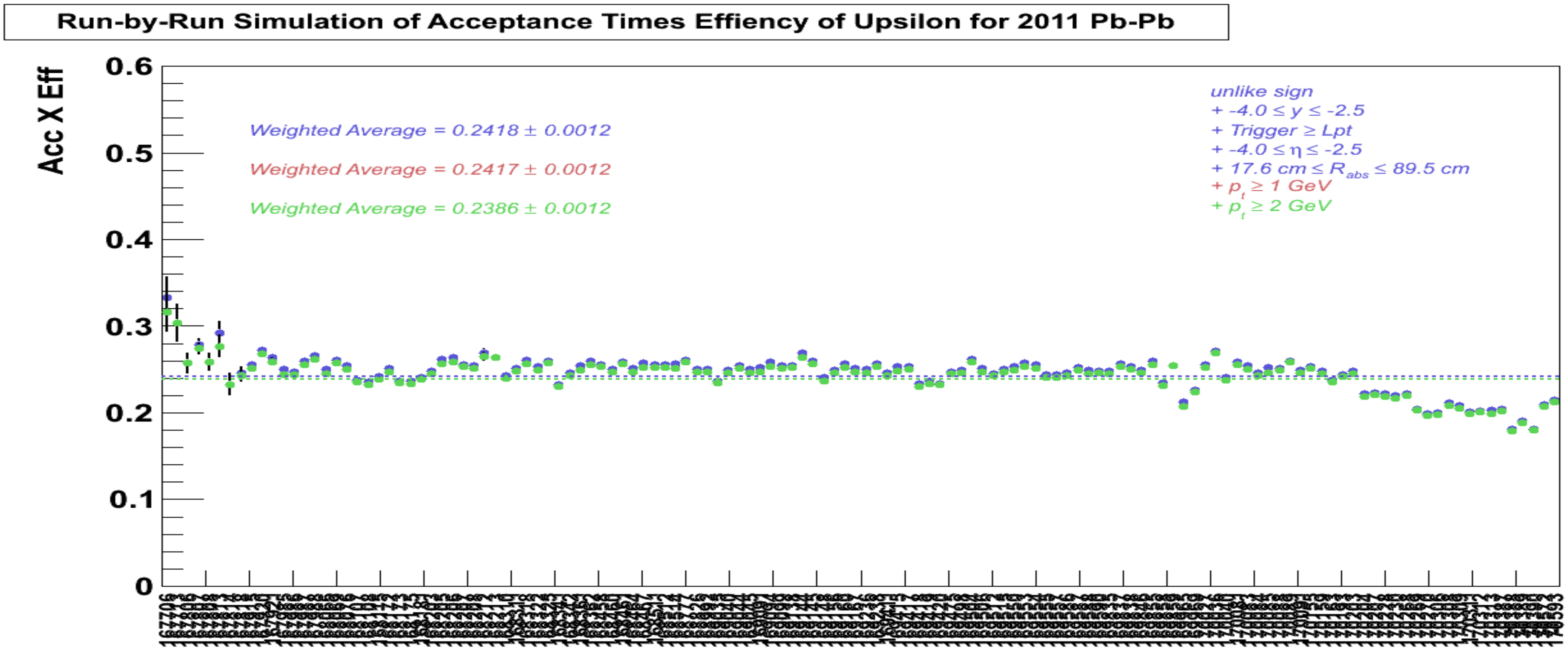
Acceptance Times Efficiency

$$A \times \varepsilon = \frac{N^{rec}_{\Upsilon}(-4 \leqslant y \leqslant -2.5)}{N^{sim}_{\Upsilon}(-4 \leqslant y \leqslant -2.5)}$$

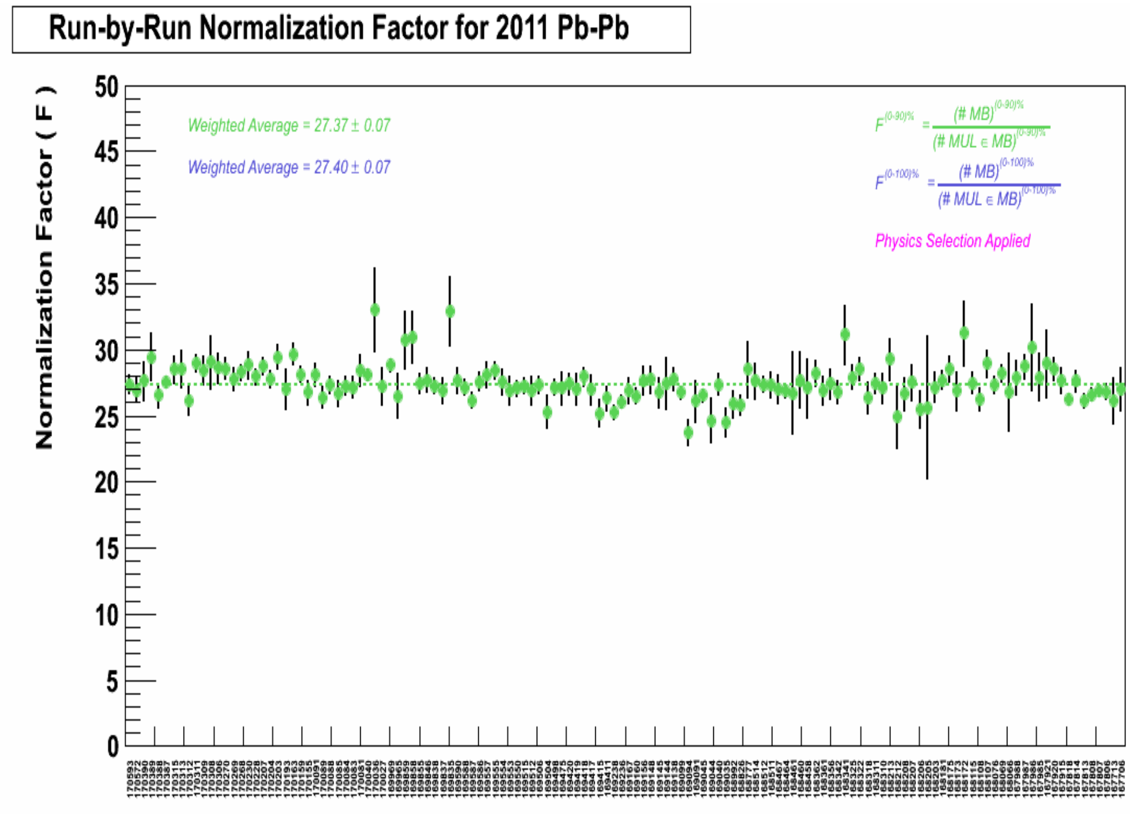
Run-by-Run Simulation of 132 runs of LHC11h (2011 PbPb) period

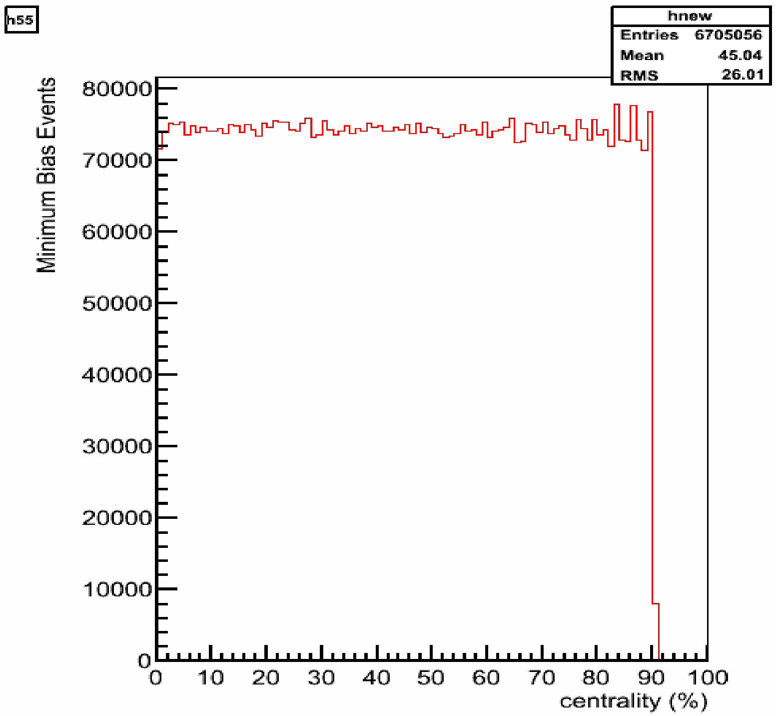
Number of simulated event proportional to run size (MUL events)





Normalization to Minimum Bias Events





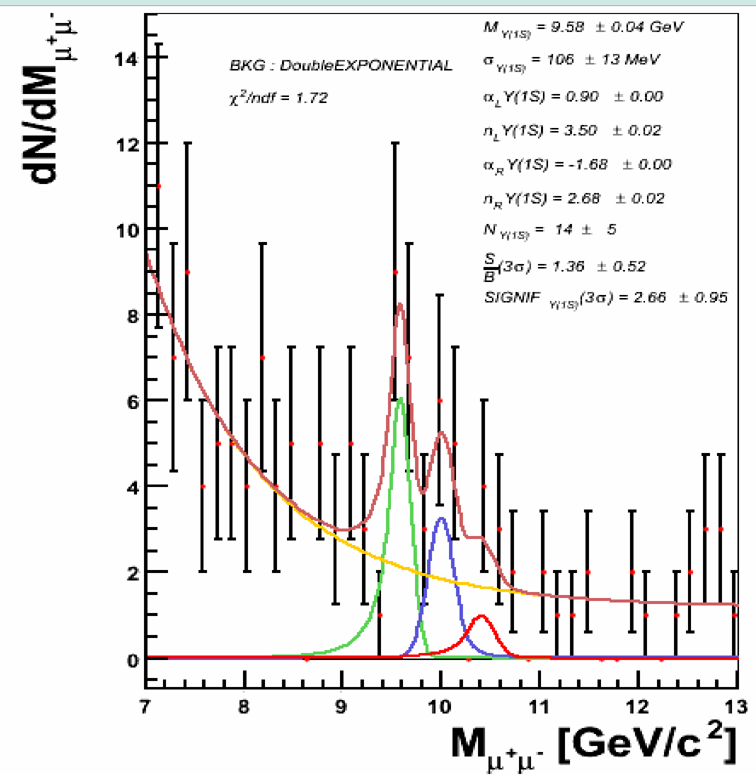
- We need to normalize signal yield by minimum bias events, but we are using MUL Trigger
- Normalization factor (F) connects the MUL trigger to the Minimum Bias Trigger

Statistical and Systematic Uncertainties

→ The dominating source of statistical uncertainties comes from signal extraction (~15 -- 22 %)

→ The dominating source of systematic uncertainty comes from pp reference cross-section (pp reference cross-section Martino and Francesco)

Upsilon @ 2.76 TeV 2013 Data



→ The systematic is divided in two parts:

Uncorrelated and Correlated

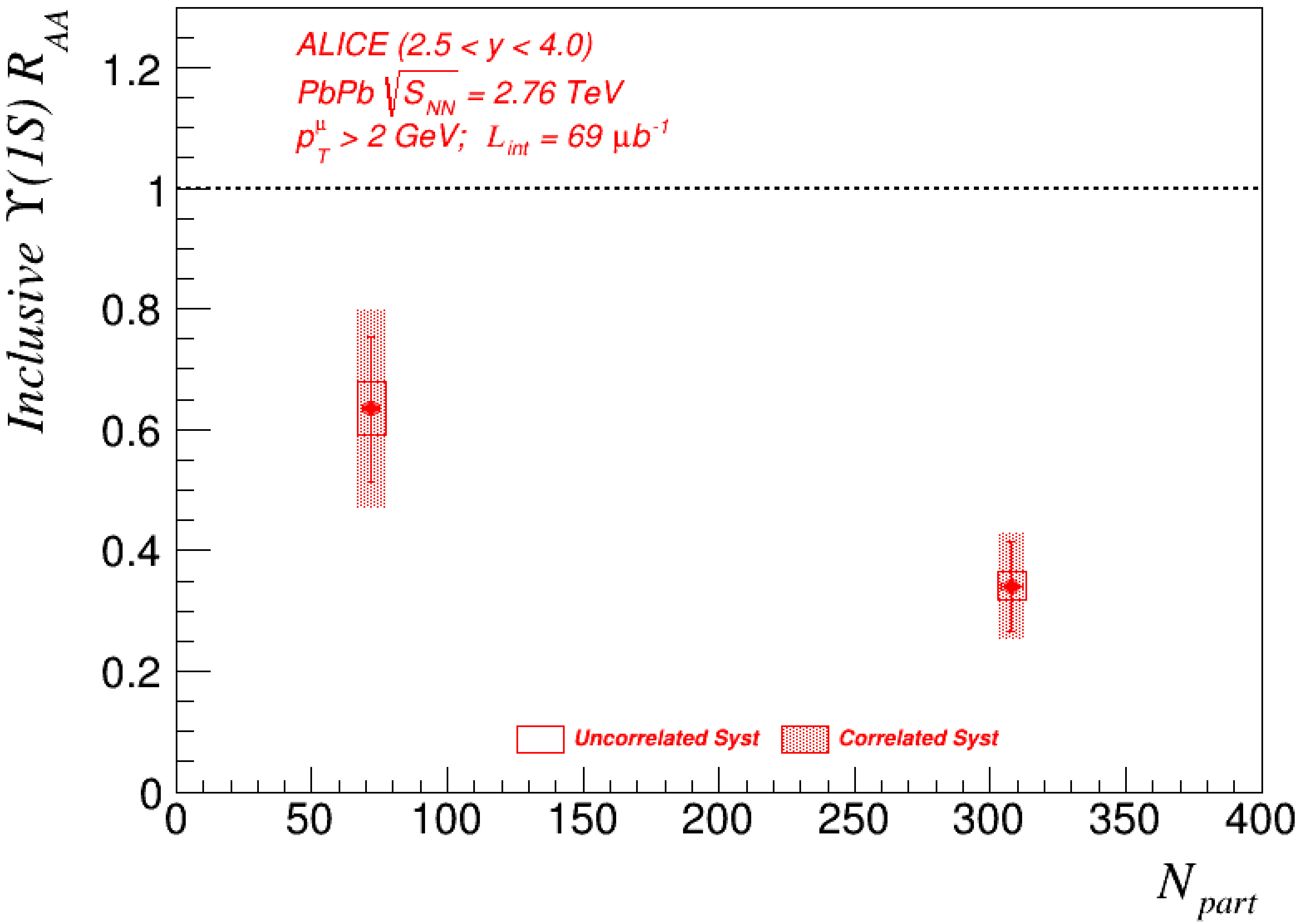
For example, pp reference cross-section does not depend on centrality but depends on rapidity.

So, pp reference cross-section systematic uncertainty for:

Centrality bins:--> Correlated

Rapidity bins:--> Uncorrelated

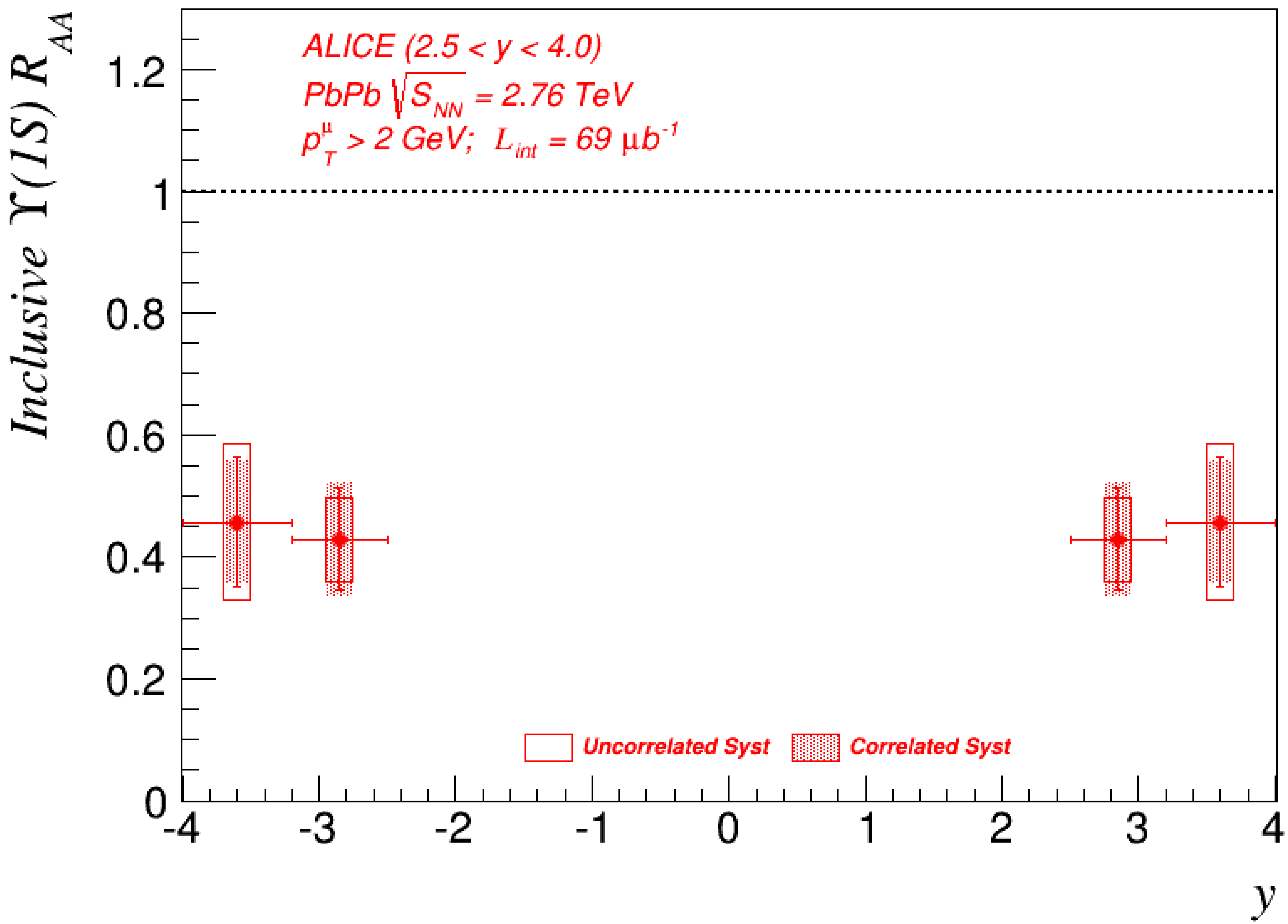
ALICE Υ(1S) R_{AA}: Centrality Dependence



→ Clear Indication of Suppression

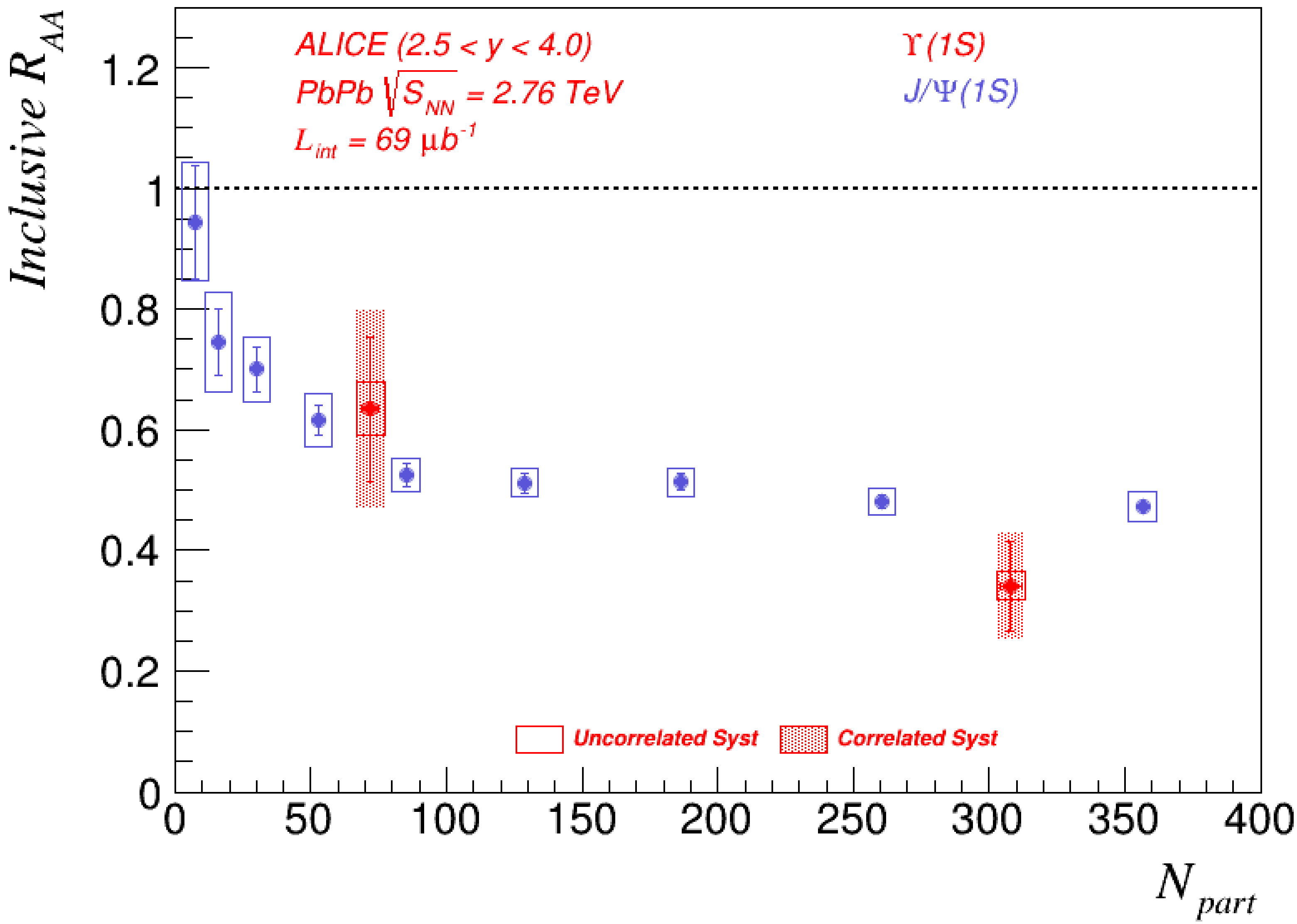
→ Suppression increases with centrality

ALICE Υ(1S) R_{AA}: Rapidity Dependence



→ No cear rapidity dependence within the large uncertainties

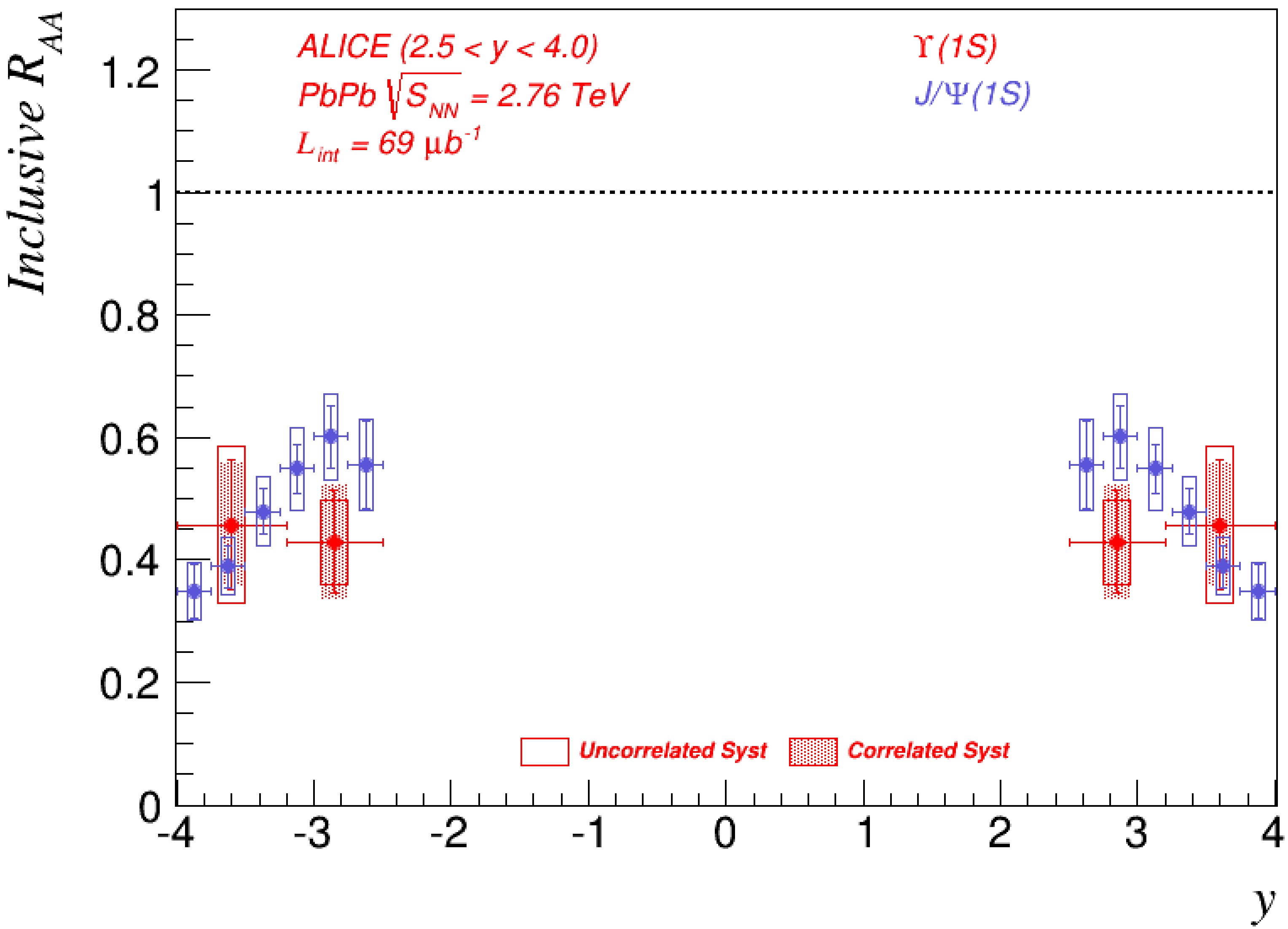
ALICE Y(1S) Vs J/psi R_{AA} Comparison: Centrality



→ At higher centrality Y(1S) suppression seems more compared to J/psi

→ Note Upsilon has much less regeneration than J/psi

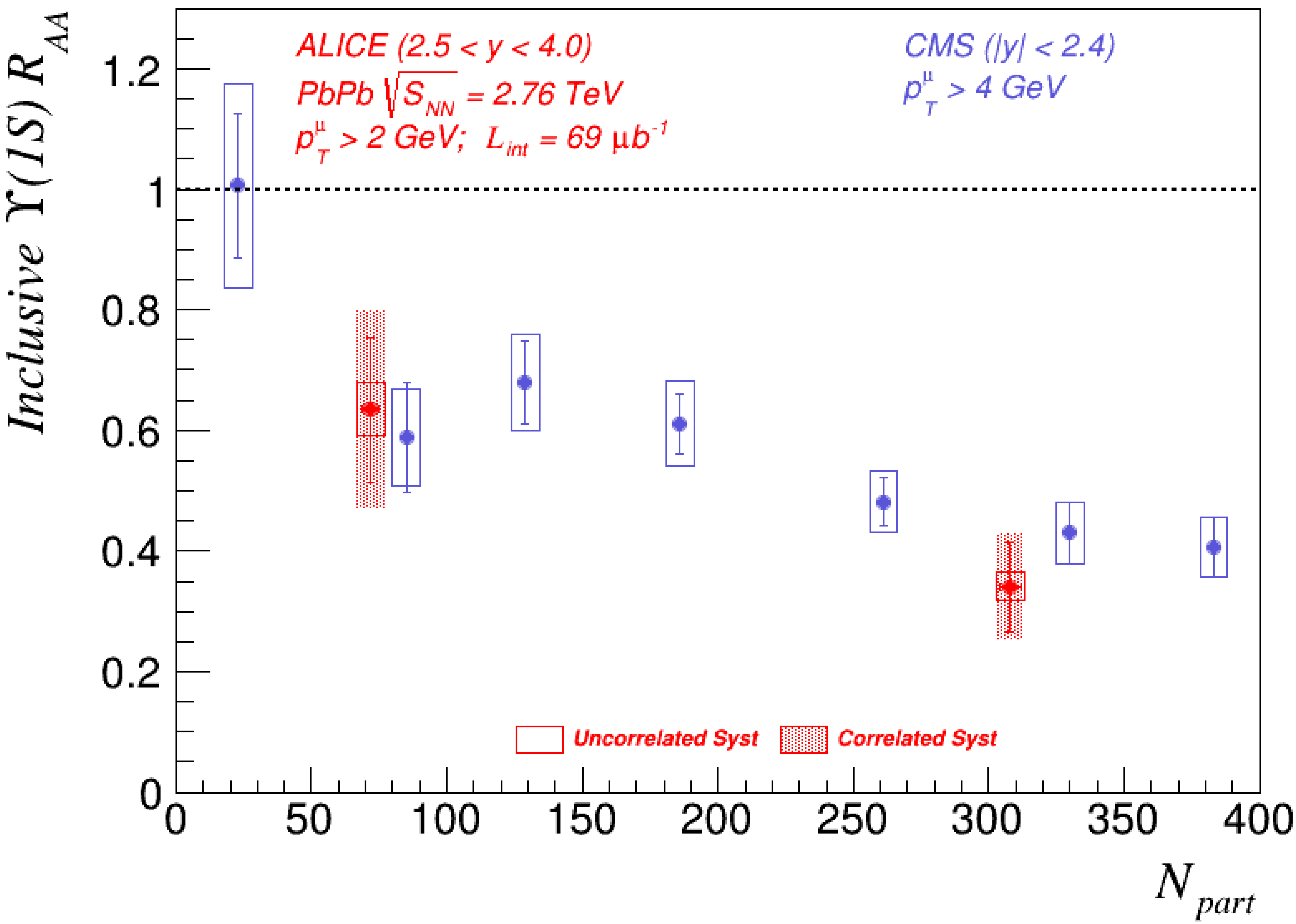
ALICE Υ(1S) Vs J/psi R_{AA} Comparison: Rapidity



→ Both results are integrated over 0-90 % centrality

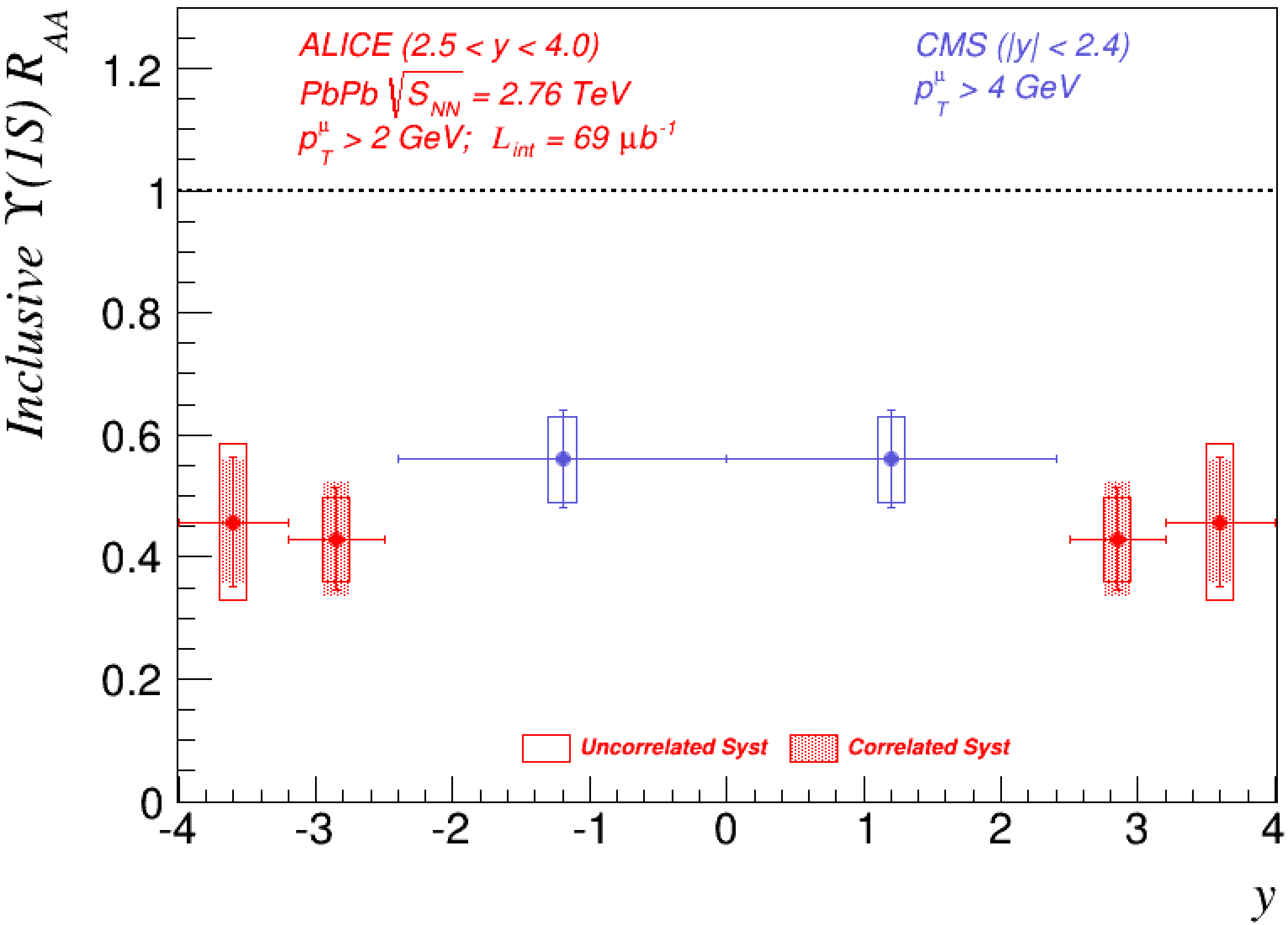
→ No different behaviour is observed compared to J/psi within the large uncertainties

ALICE Vs CMS Υ(1S) R_{AA} : Centrality



→ The suppression at forward rapidity in ALICE is compatible with mid-rapidity CMS data points for both central and semi-peripheral collisions

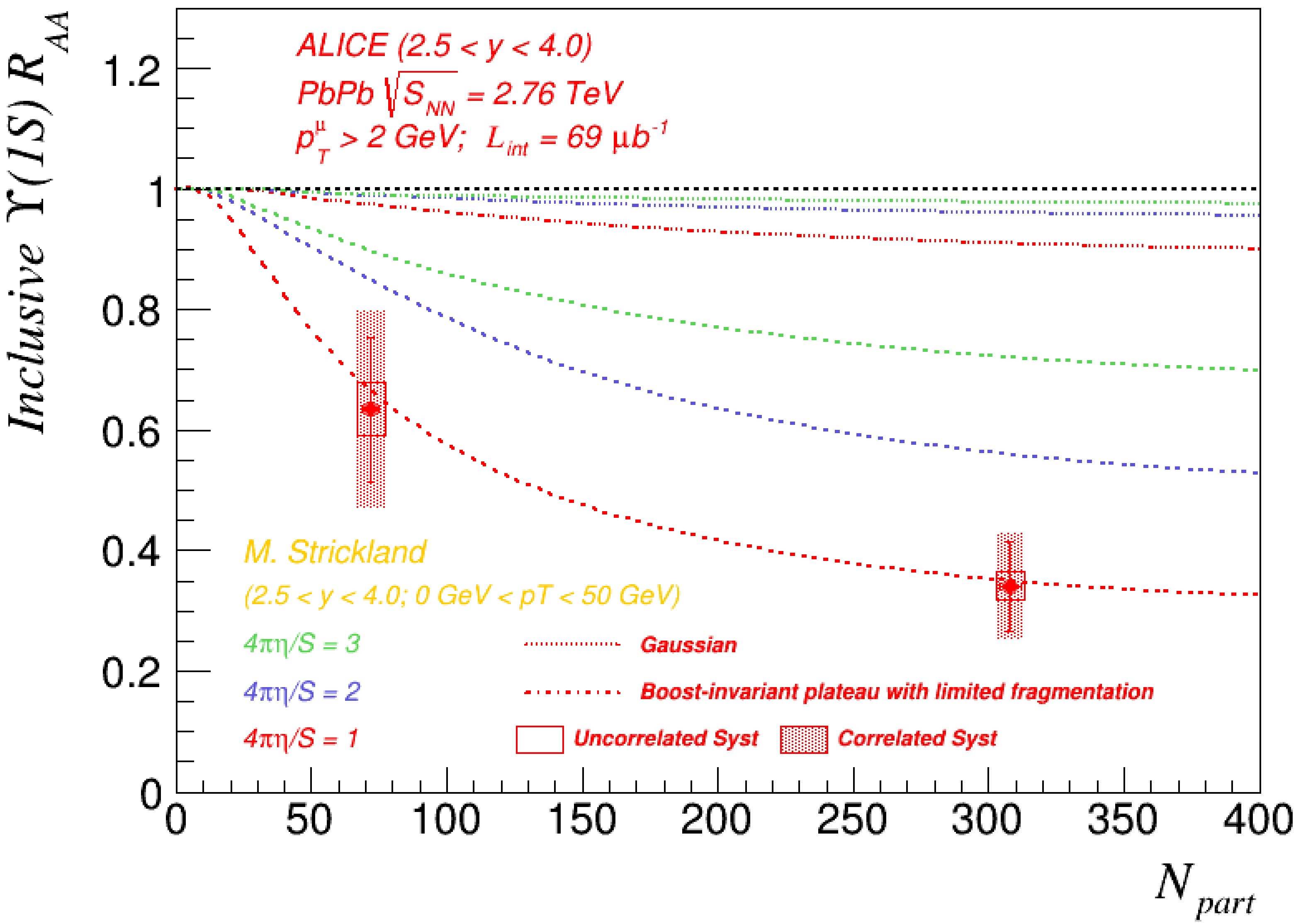
ALICE Vs CMS Υ(1S) R_{AA}: Rapidity



→ CMS data integrated 0-100 %, while for ALICE 0-90 %

→ Hint of more suppression at forward rapidity

ALICE Υ(1S) R_{AA} Vs Theoretical Model: Centrality



M. Strickland
arXiv:1207.5327

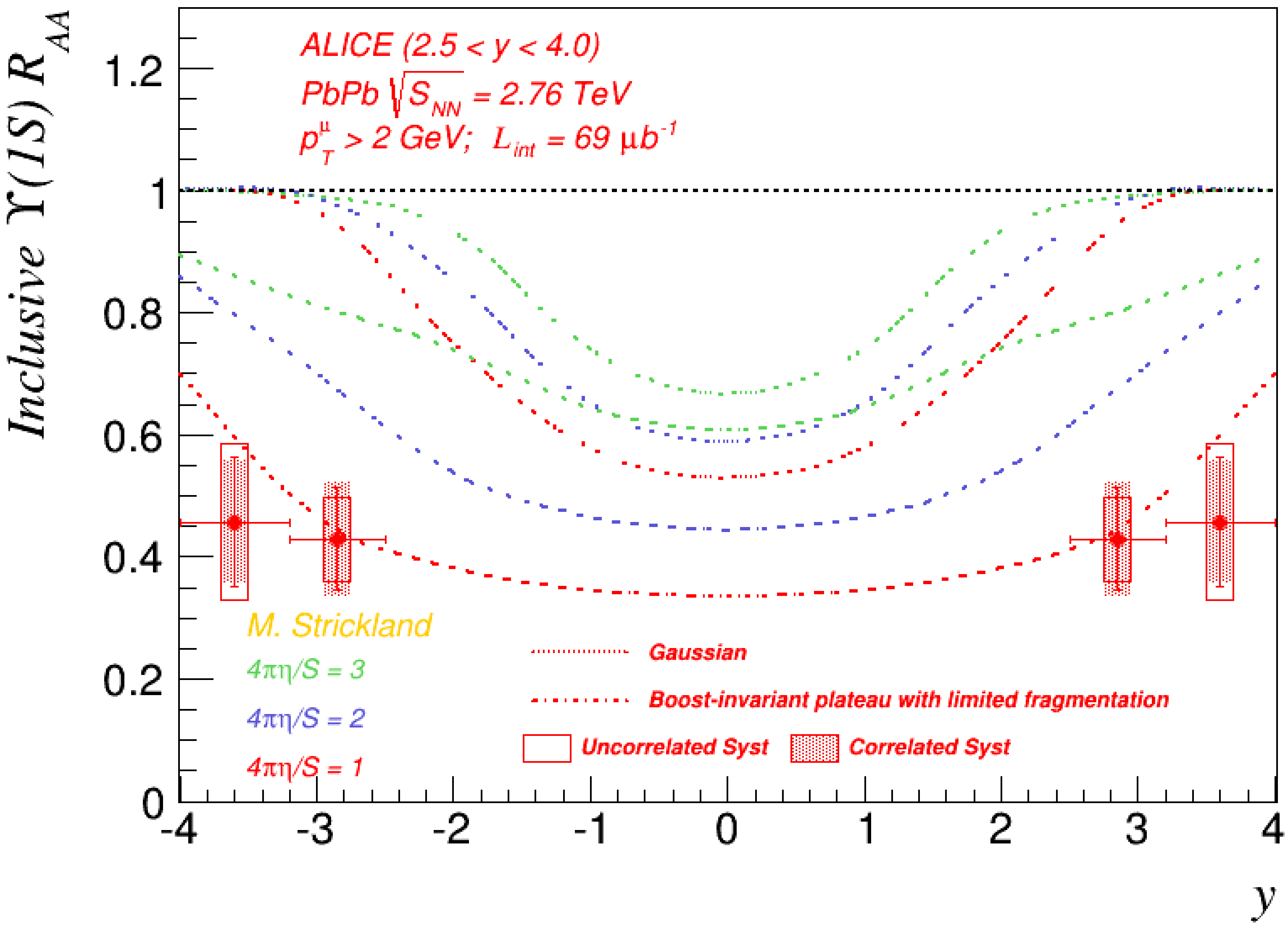
→ Model includes feed-down of Υ(1S) by higher mass states

→ Does not include recombination effect

→ Does not include cold nuclear matter effect

→ Data agrees quite well with the boost invariant plateau with limited fragmentation for shear viscosity 1.

ALICE Υ(1S) R_{AA} Vs Theoretical Model: Rapidity



→ Data agrees with the boost invariant plateau with limited fragmentation for shear viscosity 1 within the uncertainties.

→ Note that this model does not include CNM effects

→ 2013 p-Pb data can help to understand the CNM effects !

Analysis Note and Twiki

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

ALICE

CERN

ALICE-INT-2013-xxx
April 12, 2013

Measurement of the $\Upsilon(1S)$ R_{AA} in Pb-Pb collisions at $\sqrt{s_{NN}}$ =2.76 TeV with the ALICE muon spectrometer

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on behalf of the Upsilon PAG

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2. Dipartimento di Fisica Sperimentale dell'Università and Sezione INFN, Turin, Italy
3. Saha Institute of Nuclear Physics, Kolkata, India
4. INFN Sezione di Torino, Turin, Italy
5. Laboratoire de Physique Corpusculaire (LPC), Clermont Université, Université Blaise Pascal, CNRS-IN2P3, Clermont-Ferrand, France

Email: debasish.das@cern.ch, marchiso@to.infn.it, lmanceau@to.infn.it

Abstract

In the ALICE experiment, $\Upsilon(1S)$ meson can be measured in its dimuon decay channel at forward rapidity ($2.5 < y < 4$) and down to $p_T = 0$. We report on the analysis of the $\Upsilon(1S)$ nuclear modification factor in Pb-Pb collisions at $\sqrt{s_{NN}}$ =2.76 TeV . Results are discussed and compared with the J/ψ data of the ALICE muon spectrometer along with the $\Upsilon(1S)$ data from the CMS Collaboration and theoretical predictions.

Authors:
- → Loic
- → Palash
- → Massimiliano
- → Martino
- → Francesco

] Data Analysis (Loic, Palash, Massimiliano)

] Theory Part (pp reference cross-section) (Martino, Francesco)

⟶ Analysis note is ready on ALICE website

https://aliceinfo.cern.ch/Notes/node/155

→ More details of our analysis can be found in the twiki:

https://twiki.cern.ch/twiki/bin/viewauth/ALICE/MuonPbPbQA2011

Public Note and Paper Writing in Progress ...

First Heavy-Ion Result on Upsilon at Forward Rapidity !

p-Pb and Pb-p ANALYSIS

R_{pA} and R_{FB}

Nuclear Modification Factor R_{pA} :

$$R_{pA} = \frac{N_{pA}^{\Upsilon(1S)}}{\langle AccxEff \rangle_{pA}^{\Upsilon(1S)} \ x \ \langle T_{pA} \rangle \ x \ N_{pA}^{MB} \ x \ \Delta y \ x \ BR^{\Upsilon(1S)} \ x \ \sigma_{pp}^{\Upsilon(1S)}}$$

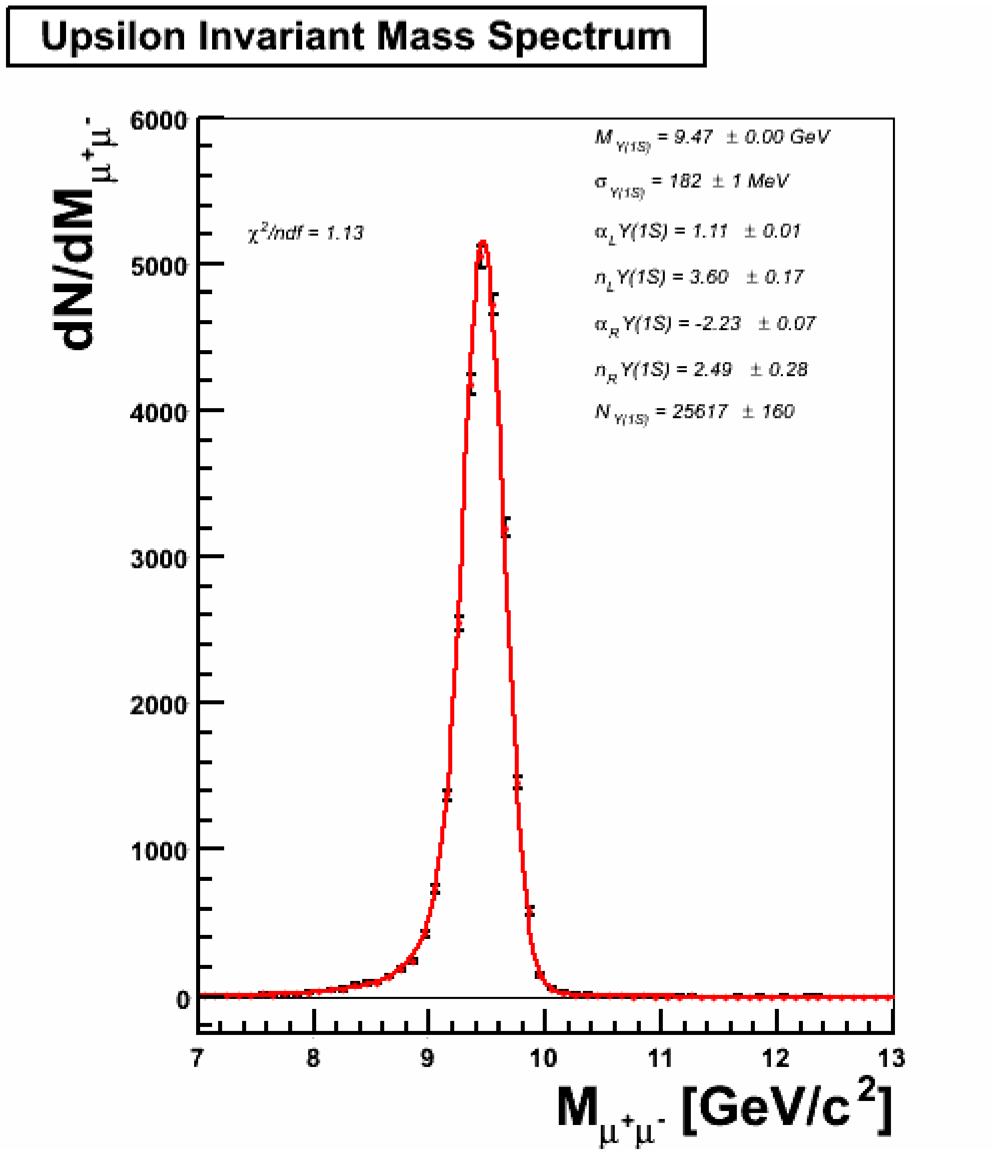
* T_{pPb} = 0.0983 ± 0.0035 mb^{-1} (arXiv: 1210.4520)

* BR*dSigma/dy → 945 +62-76 (norm) + 27-56 (extrap) pb for pPb
→ 510 +34-41 (norm) +35-95 (extrap) pb for Pbp
(Francesco, Martino Upsilon PAG meeting 20/02/2013)

Forward Backward Ratio R_{FB} :

$$R_{FB}^{\Upsilon(1S)} = \frac{R_{pA}^{\Upsilon(1S)}}{R_{Ap}^{\Upsilon(1S)}} = \left(\frac{N_{pA}^{\Upsilon(1S)}}{N_{Ap}^{\Upsilon(1S)}} \right) X \left(\frac{\langle AccxEff \rangle_{pA}^{\Upsilon(1S)}}{\langle AccxEff \rangle_{Ap}^{\Upsilon(1S)}} \right) X \left(\frac{N_{pA}^{MB}}{N_{Ap}^{MB}} \right)$$

Simulation

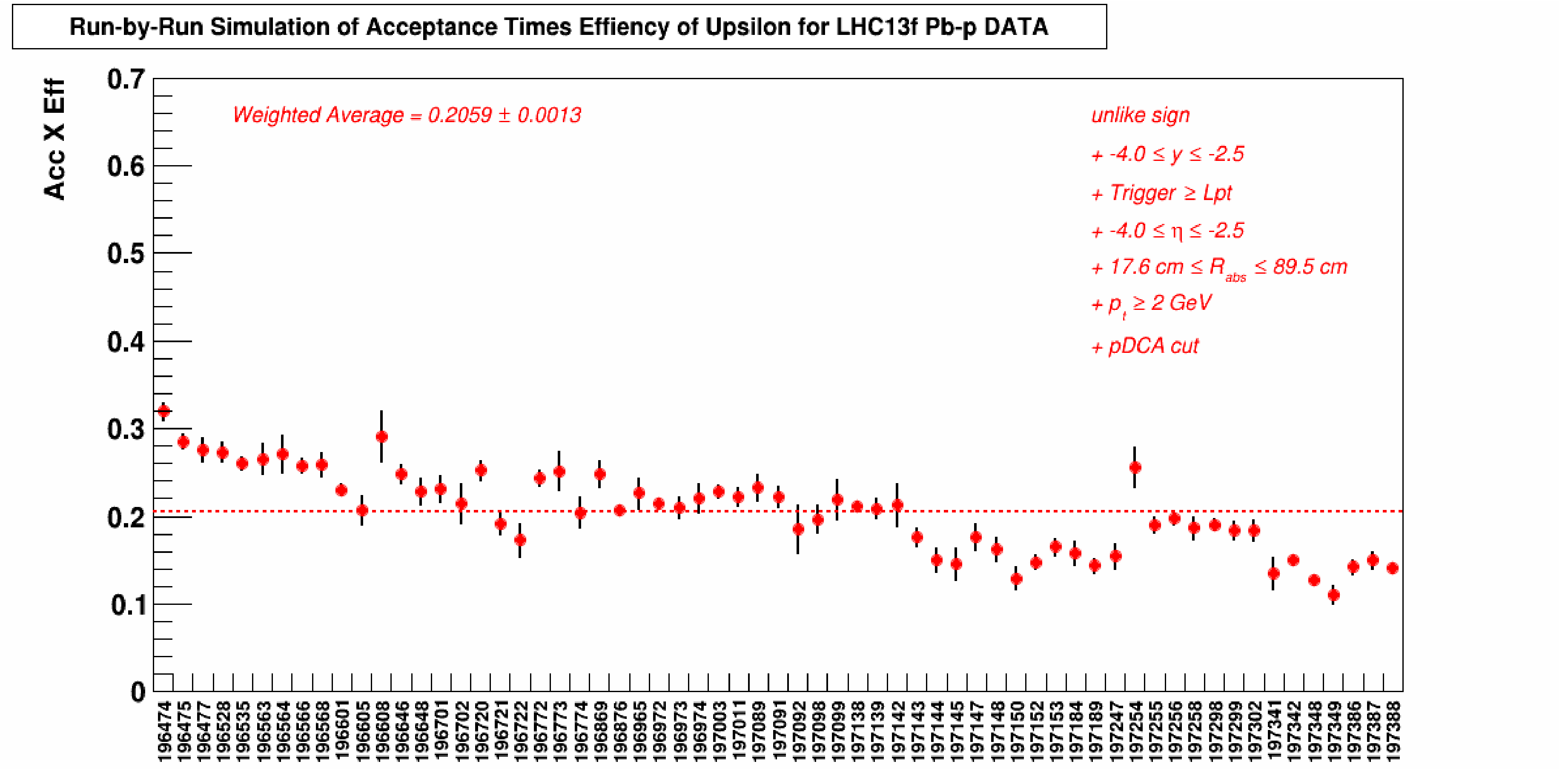


→ Run-by-run simulation
→ Generator: AliGenMUONlib::kUpsilon
→ Parametrization: “Pbp 5.02”

Simulation:
→ /alice/simulation/2008/v4-15-Release/Ideal
→ Realistic vertex from OCDB
→ VertexSmear

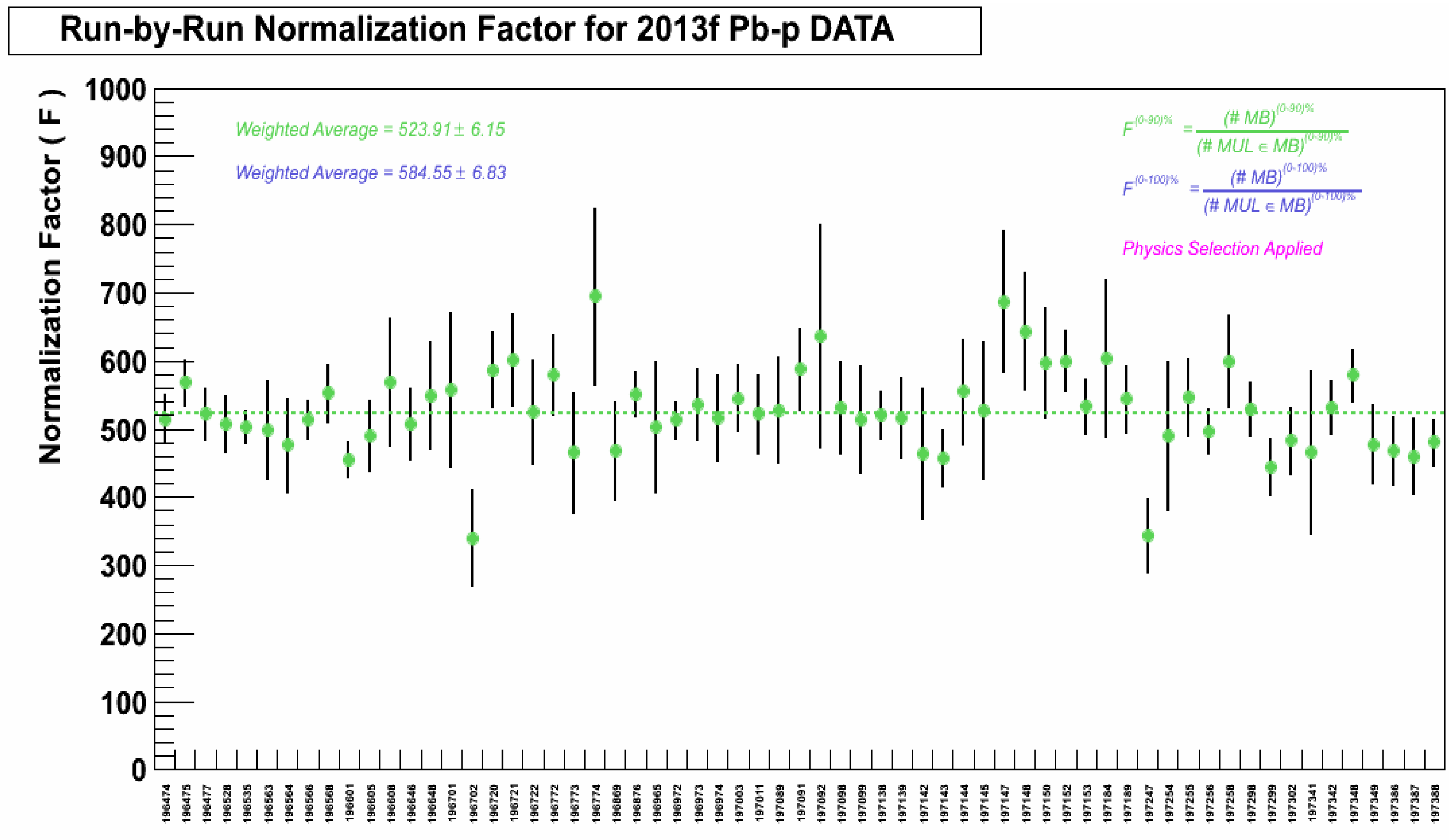
Reconstruction:
→ /alice/simulation/2008/v4-15-Release/Residual
→ Vertex reconstructed at zero

Acceptance Times Efficiency



→ Total 64 Runs from LHC13f Simulated

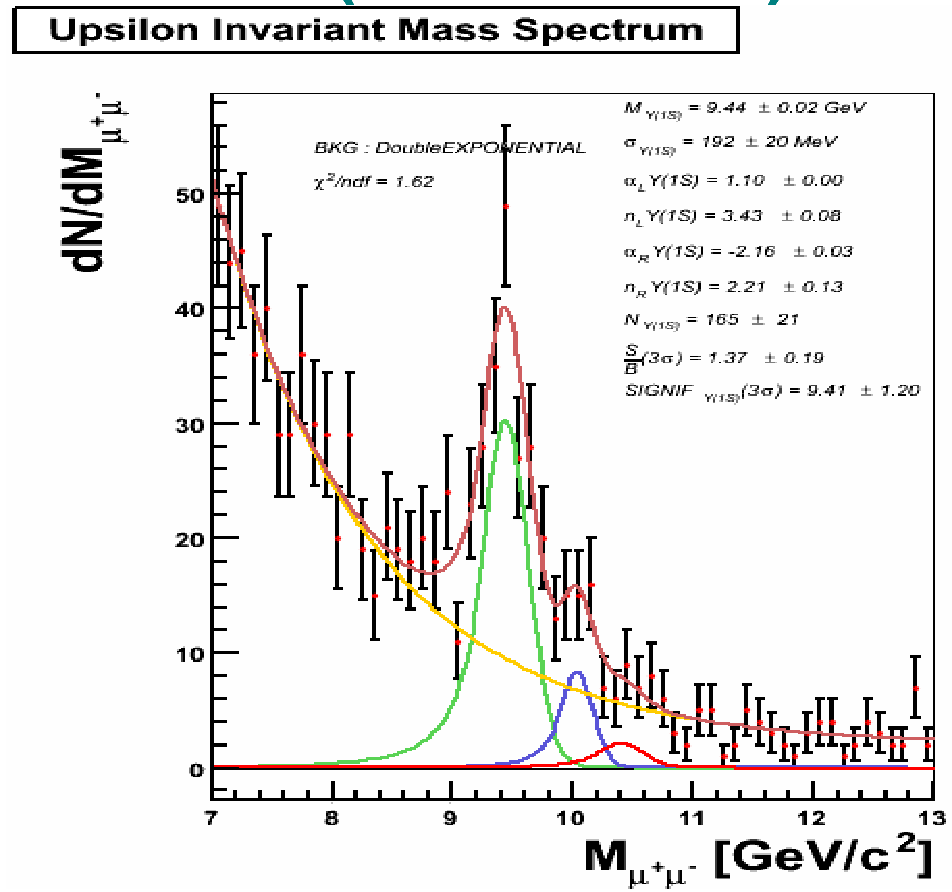
Normalization to Minimum Bias



→ Analized MUL trigger 20.55 M

→ Equivalent Minimum Bias Event 10766.35 M

Signal Extraction (LHC13f)



Event Cuts:
Physics Selection
CMUL Trigger
Centrality (0-90) %

Muon Cuts:
Trigger Matched Track (Lpt,Lpt)
$-4.0 < \eta < -2.5$
17.6 cm < R abs < 89.5 cm
pDCA Cut
pT >= 2 GeV

Dimuon Cuts:
$-4.0 < y < -2.5$

$$M_{\Upsilon(2S)} = M^{PDG}_{\Upsilon(2S)} + \left(M^{FIT}_{\Upsilon(1S)} - M^{PDG}_{\Upsilon(1S)} \right) \frac{M^{PDG}_{\Upsilon(2S)}}{M^{PDG}_{\Upsilon(1S)}}$$

$$M_{\Upsilon(3S)} = M^{PDG}_{\Upsilon(3S)} + \left(M^{FIT}_{\Upsilon(1S)} - M^{PDG}_{\Upsilon(1S)} \right) \frac{M^{PDG}_{\Upsilon(3S)}}{M^{PDG}_{\Upsilon(1S)}}$$

$$\sigma_{\Upsilon(2S)} = \sigma_{\Upsilon(1S)} \frac{M^{PDG}_{\Upsilon(2S)}}{M^{PDG}_{\Upsilon(1S)}} \qquad \sigma_{\Upsilon(3S)} = \sigma_{\Upsilon(1S)} \frac{M^{PDG}_{\Upsilon(3S)}}{M^{PDG}_{\Upsilon(1S)}}$$

→ Signal fitted with Double Crystal Ball

→ Tail parameters taken from pure simulation

→ Mass, Sigma and Amplitude free for Y(1S)

→ Amplitude of Y(2S) and Y(3S) kept free

Systematic From Signal Extraction

Following sources of systematics have been considered:

1. Background Fit Function
   (Double Exponential and Double Power Law)
2. Mass Scaling of Υ(2S) and Υ(3S)
3. Sigma Scaling of Υ(2S) and Υ(3S)
4. Scaling of CB tail parameter alpha of Υ(2S) and Υ(3S)
5. Scaling of CB tail parameter n of Υ(2S) and Υ(3S)

$$N_{\Upsilon(1S)} = N^{cent}_{\Upsilon(1S)} \pm N^{stat}_{\Upsilon(1S)} \pm N^{syst}_{\Upsilon(1S)}$$

$$N^{cent}_{\Upsilon(1S)} = \frac{\sum N^{i}_{\Upsilon(1S)}}{n}$$

$$N^{stat}_{\Upsilon(1S)} = \frac{\sum Error\ N^{i}_{\Upsilon(1S)}}{n}$$

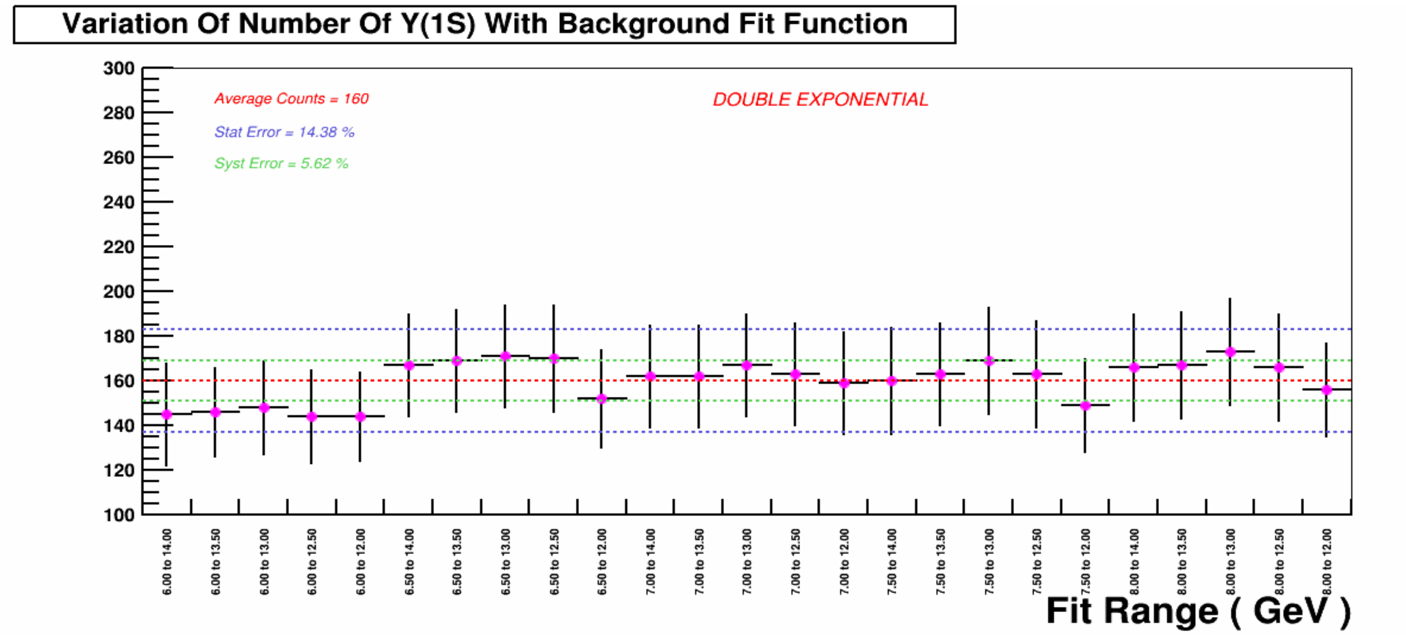
$$N^{syst}_{\Upsilon(1S)} = \sqrt{\frac{\sum (N^{i}_{\Upsilon(1S)} - N^{cent}_{\Upsilon(1S)})^2}{n}}$$

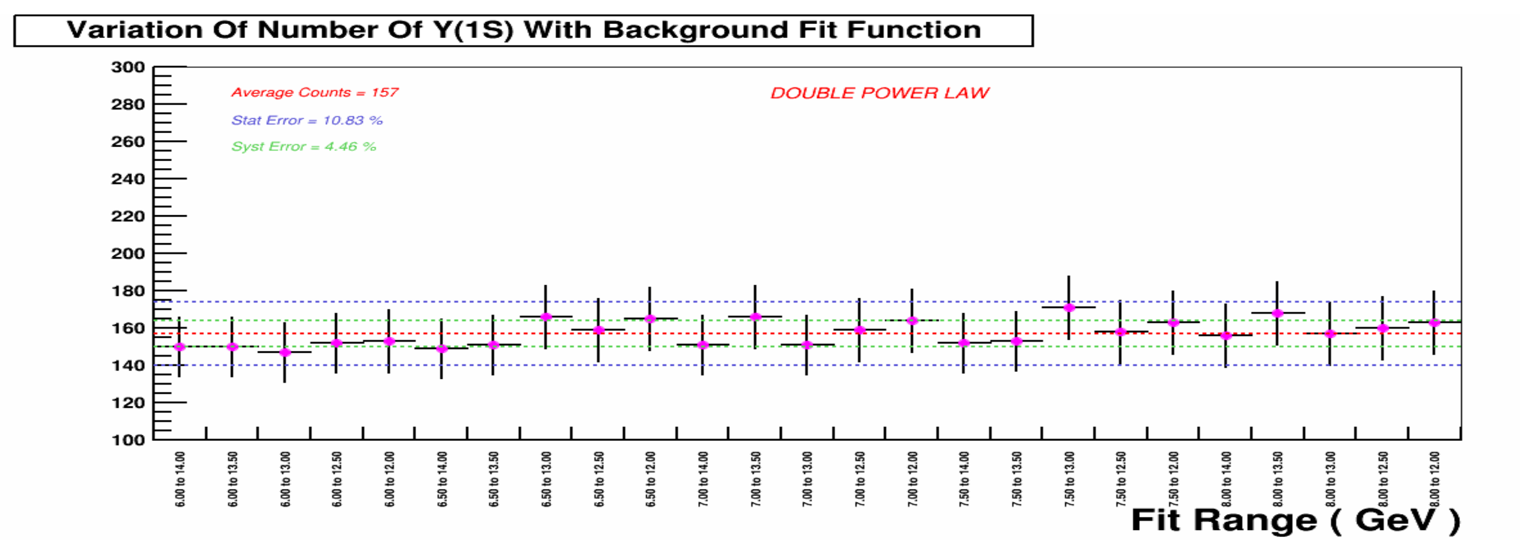
→ Central value is the arithmetic average between results of reliable fits

→ Statistical error is the average value of statistical uncertainties

→ Systematic error is the RMS value between results of reliable fits for a given source of systematic

Systematic From Background Fit Function





Two Background function used:

1. Double Exponential

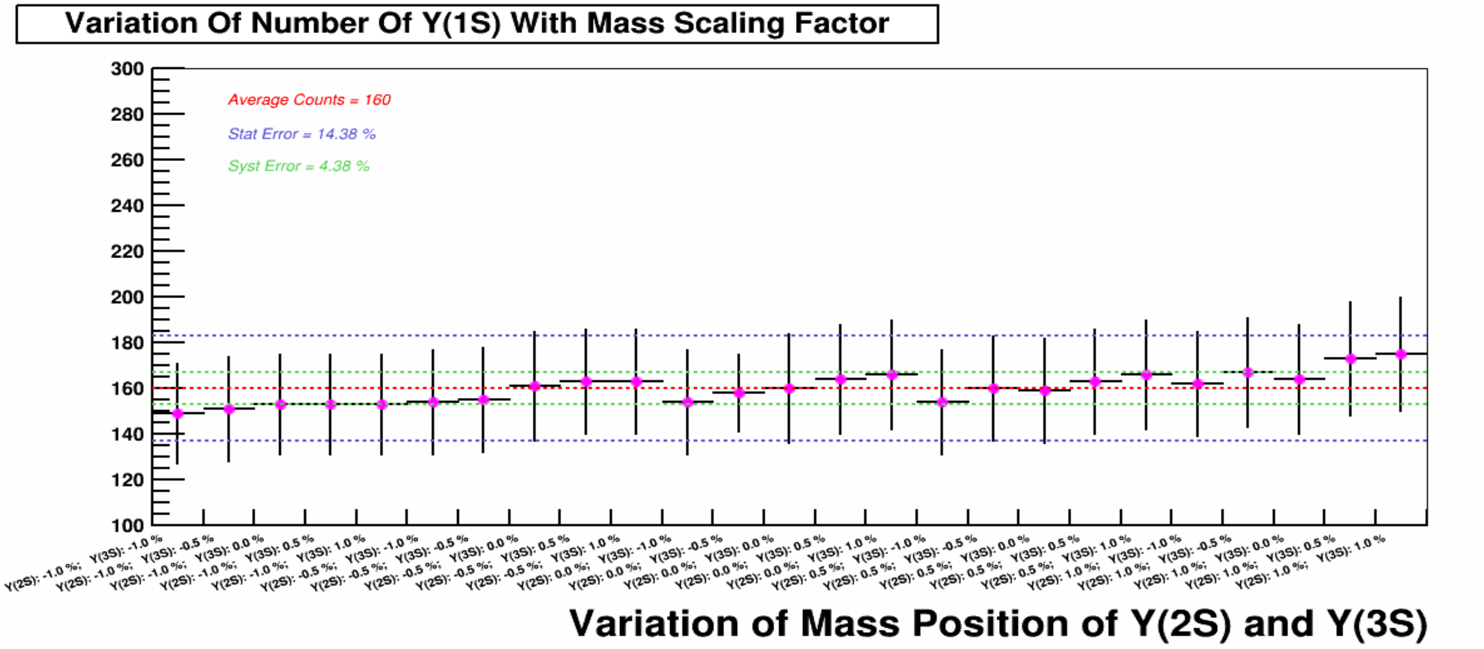
2. Double Power Law

→ Fit range varied for various combination of mass between (6.00-8.00)GeV and (12.00-14.00) GeV

→ Statistical uncertainty large ~ 10-15 %

→ Systematic error ~ 4-6 %

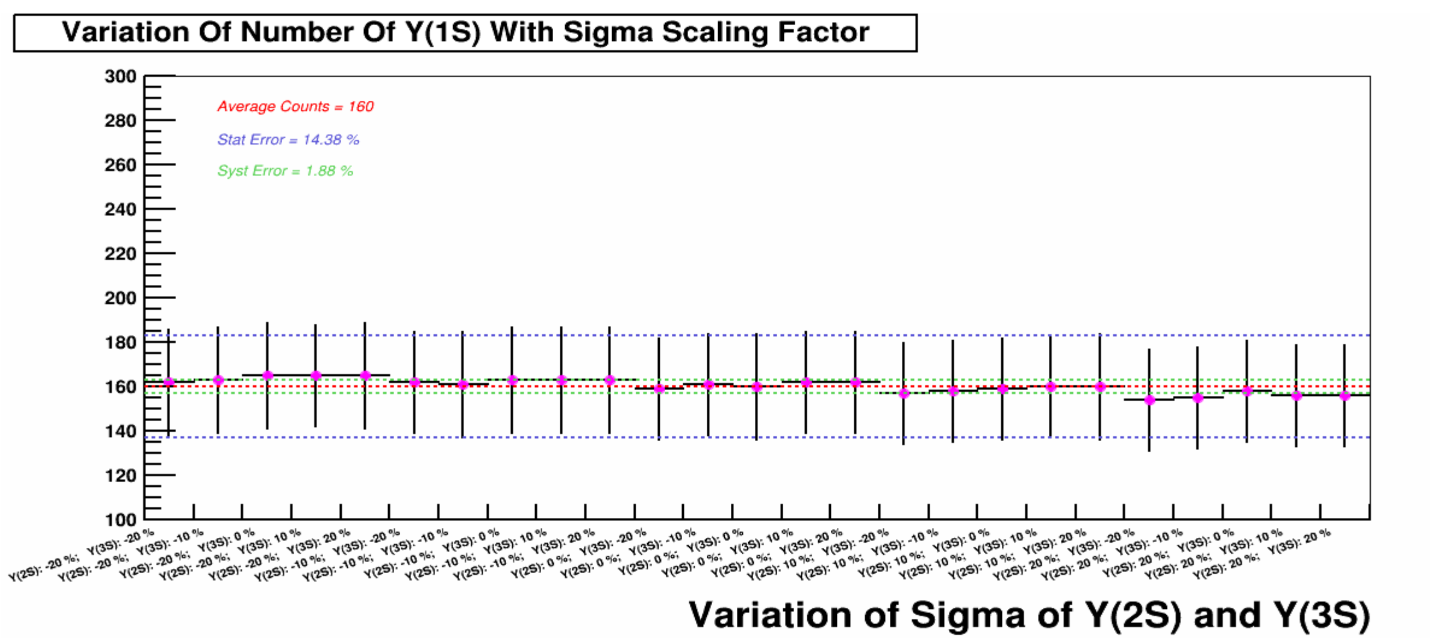
Mass and Sigma Scaling Factor



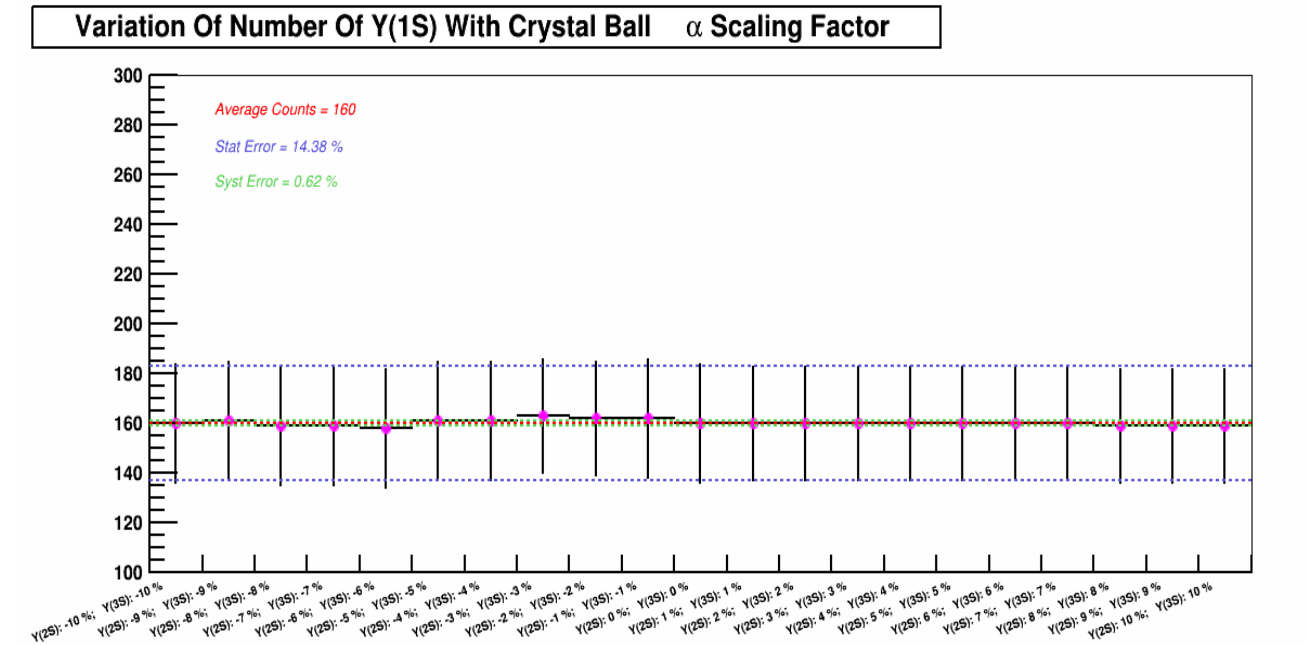
→ Systematic Uncertainty:

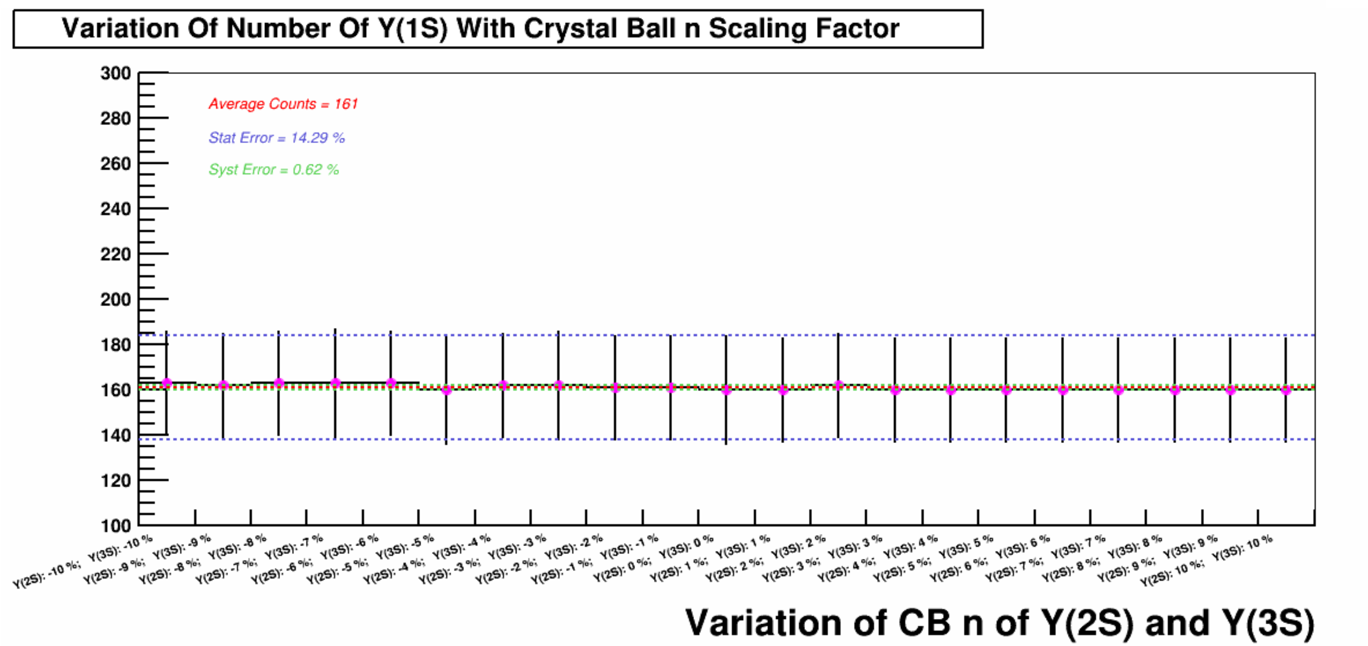
Mass Scaling: ~ 4.38 %

Sigma Scaling: ~ 1.88 %



Crystal Ball α and n Scaling Factor





→ Systematic Uncertainty

CB alpha and n: ~ 0.6 %

Systematic From Signal Extraction: Summary

Source of Systematic	Central Value	Stat Error	Syst Error
BKG Fit Function Double Exponential	160	23	9
BKG Fit Function Double Power Law	157	17	7
Mass Scaling	160	23	7
Sigma Scaling	160	23	3
Crystal Ball α Scaling	160	23	1
Crystal Ball n Scaling	161	23	1
TOTAL	160	22	14

Central Value : Arithmetic Average

Stat Error: Arithmetic Average

Syst Error: Quadratic Sum

--> Statistical Error ~ 13.75 %

→ Systematic Error ~ 8.75 %

→ Dominant Source of Systematic is the BKG Fitting Function (~ 6.88 %) and MSF (~ 4.38 %)

Forward Backward Ratio

$$R_{FB} = R_{pPb} / R_{Pbp}$$

Quantity	NLO Predictions (Sambat 27th Feb Upsilon PAG)	My Result
R_{pA}	0.88 ± 0.04 (syst)	0.697 ± 0.077 (stat) ± 0.098 (syst)
R_{Ap}	1.13±0.04 (syst)	0.960 ± 0.133 (stat) ± 0.119 (syst)
R_{FB}	0.78 ± 0.06 (syst)	0.73 ± 0.18 (stat) ± 0.19 (syst)

Summary and Game Plan

→ 2011 Pb-Pb data has been analyzed, Upsilon R_{AA} extracted

→ Analysis note ready on ALICE website, Public Note and Paper on progress ...

→ 2013 p-Pb and Pb-p data analysis started

→ More work is to be done

→ Game plan is to write analysis note on p-Pb Upsilon analysis !

THANK YOU